Towards Accurate, High-Frequency I-V Curve Measurements of Photovoltaic Modules Applying Electronic Loads

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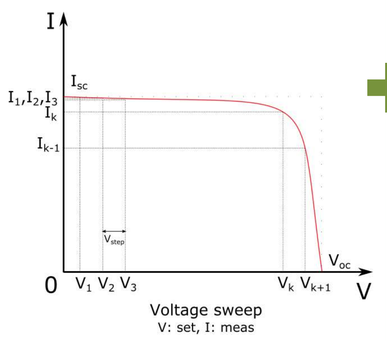
Aim of the work

The aim of this paper is to demonstrate a new measurement methodology for accurate, high-frequency I-V characterization of PV modules under outdoor conditions. This novel method enables I-V measurements up to 1 Hz (which is essential for accurate yield estimations) while maintaining a low computational effort.

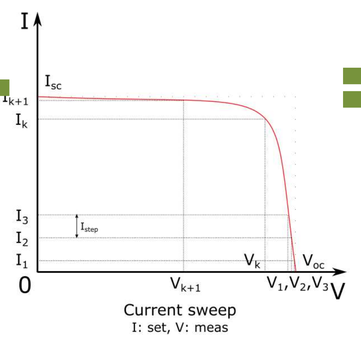
Hybrid sweeping

Both a voltage and a current controlled sweeps are applied. They emphasize different parts of the I-V curve.

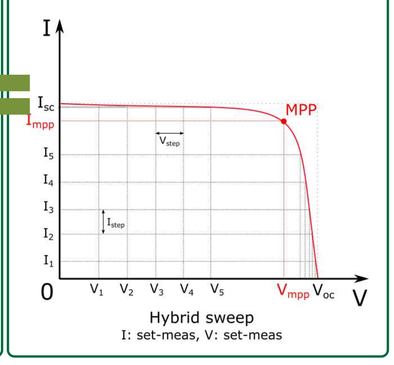
Voltage Sweep
Horizontal near-flat
0-V_{oc} equidistant



Current Sweep
Vertical near-flat
0-0.95I_{sc} equidist.

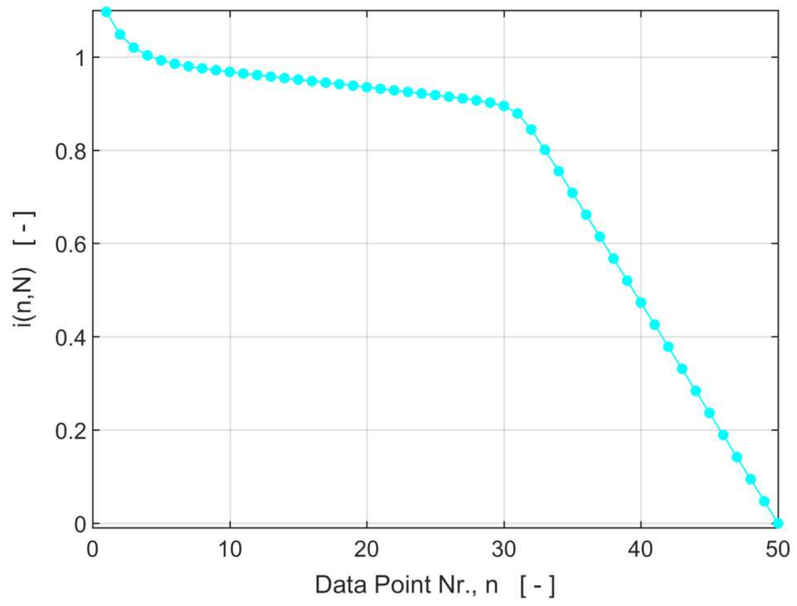


Hybrid Sweep



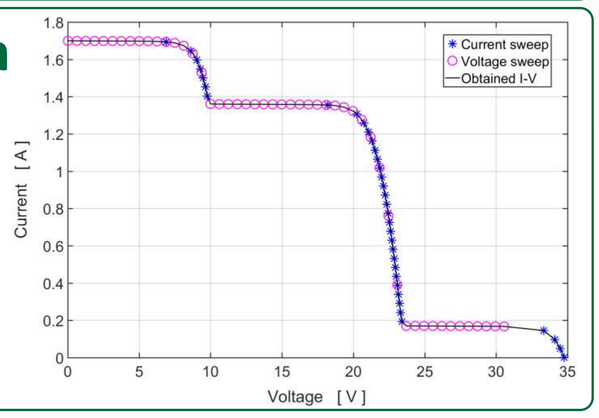
Optimized current-controlled sweep

Scalable function ***i***(**n**,**N**) of the data point number **n** and the total number of points per I-V curve, **N** (here **N** = 50). $\mathbf{I_{sc}}$ = 1



Hybrid sweep simulation

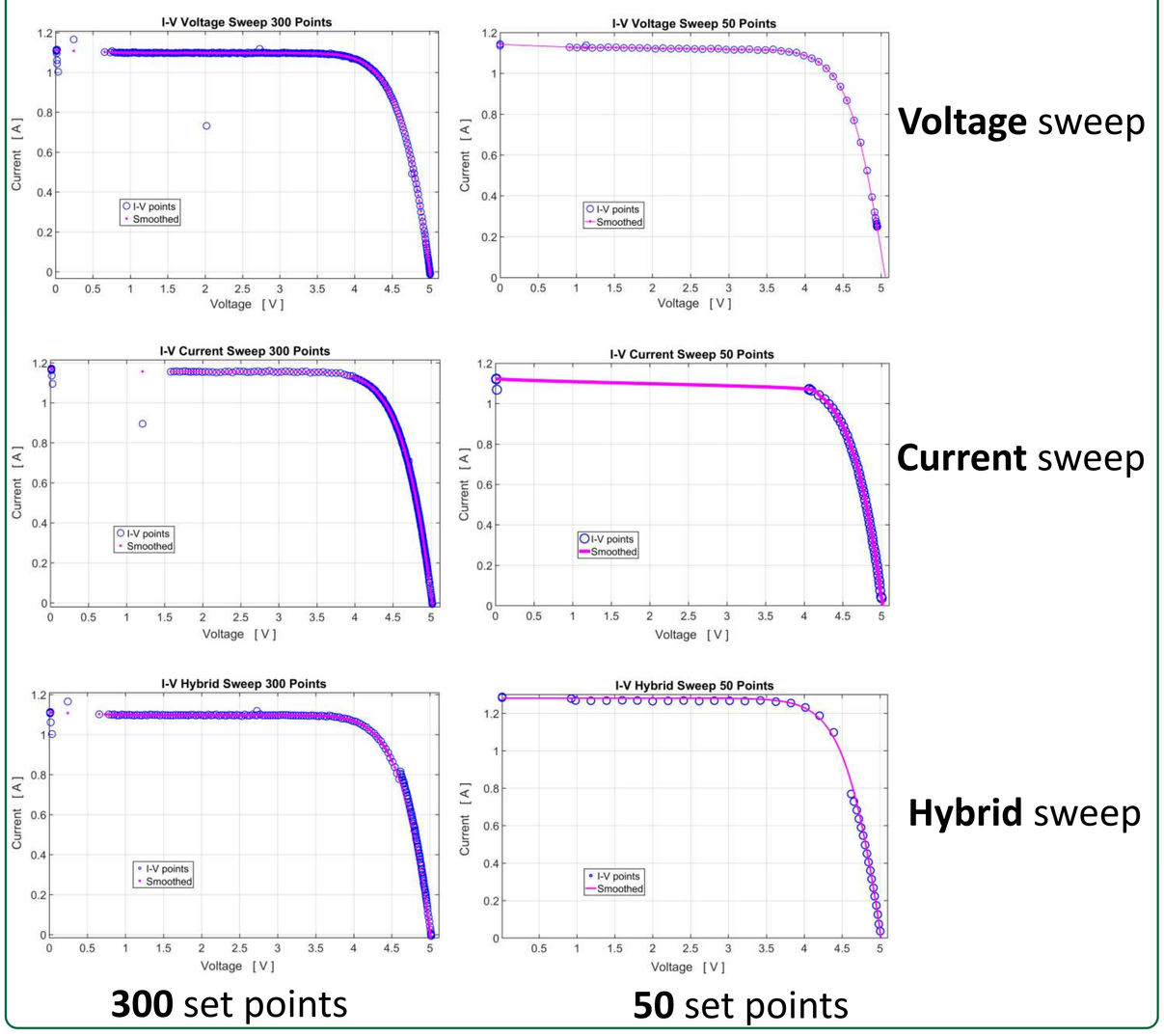
60-cell c-Si module
3 bypass diodes
Shaded sub-strings 2 & 3
Note: incomplete V sweep!
50 points in each sweep



Experimental Setup & Methodology

H & H PMLI multichannel electronic loads
NI cRIO-9022 controller + NI-9205 + NI-9264 DAQ modules
4-wire I-V measurements; modules biased by +5 V PSUs
Sweeping all 8-10 modules every 15 s; I-V sweep takes 6 s
Data uploaded to a DB server; queried from web interface

Current & Voltage vs. Hybrid sweep (0.1 s)



Voltage sweep

Current sweep

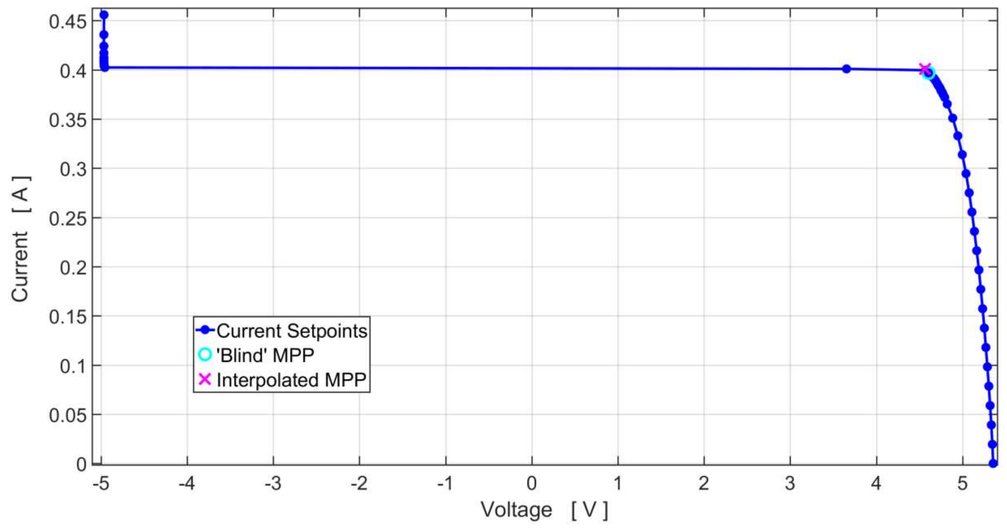
Hybrid sweep

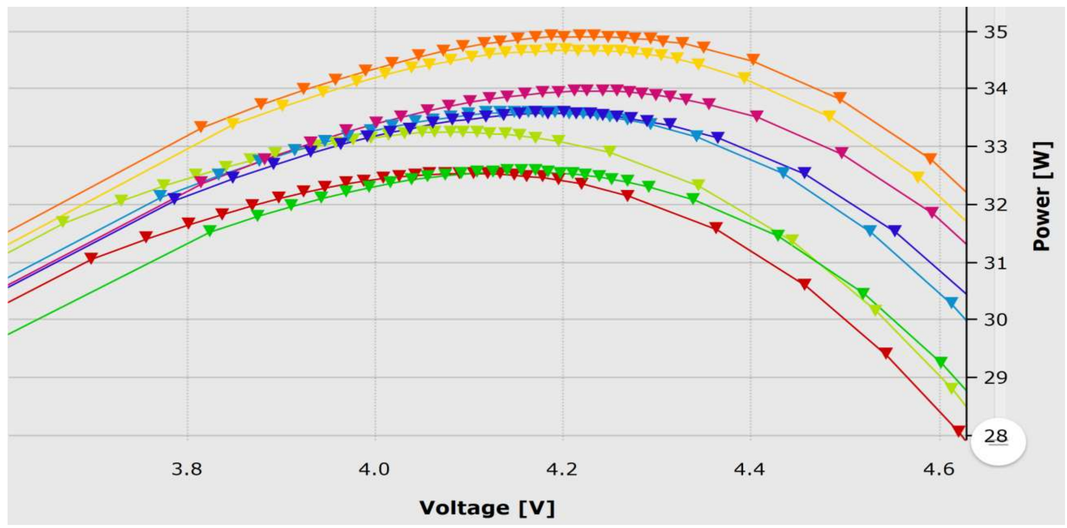
300 set points

50 set points

Results, optimized current-controlled sweep

9-cell research c-Si modules, no bypass diodes:





Conclusions

- This work presented conceptually new techniques that provide **fast** yet **accurate** I-V curve estimation. The latter is essential for precise energy-yield estimation during highly varying weather conditions.
- Hybrid sweeping allows a significant **reduction of measurement points**, accurate **determination of $\mathbf{R_P}$ and $\mathbf{R_S}$**, use of **equidistant measurement points** and hence high-resolution expensive equipment is not necessary.
- Optimized current control steps/setpoints offer good resolution about the MPP with only 50 data points. (Note: no bypass diodes.)